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REVIEW OF THE LATEST TECHNOLOGY IN CARTOGRAPHIC DATA ACQUISITION, MANIPULATION, STORAGE AND PRESENTATION, WITH SPECIAL EMPHASIS ON POTENTIAL APPLICATIONS IN DEVELOPING COUNTRIES: HYDROGRAPHIC SURVEYING AND NAUTICAL CHARTING

Office of Coast Survey: chart production modernization

Paper submitted by the United States of America**

Summary

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INTRODUCTION

NOAA's Office of Coast Survey (CS) is responsible for providing the Nation a national suite of nautical charts and Coast Pilots, and a comprehensive suite of oceanographic observations and predictions. This national folio of 1,000 nautical charts and nine Coast Pilots and the tide and current observations and predictions for the major ports and estuaries of the United States underpins a suite of marine navigation services which sustains and enhances the Nation's economy; protects life, property, and the environment; promotes commercial and recreational use of the Nation's waterways; and maintains National Security.

For almost three decades, automation has affected how CS carries out the activities that provide these navigation services - both in data collection and product preparation. But, these automated techniques have served primarily to improve the throughput for techniques and processes which represent more than a century of experience and tradition. Fundamental paradigms were not changing. Now, as the program approaches the end of the 20th century, computer and communication technologies have become so pervasive, cost effective, and powerful, these old paradigms are about to be discarded. This paper discusses how the Coast Survey is modernizing its "nautical chart" production activity and how this modernization is challenging the established ways of "doing business" - challenges which will lead to a suite of comprehensive and integrated navigation services.

REQUIREMENTS FOR PRODUCTS

There is little doubt of the strong support for continuing to make nautical charts available in paper form to serve the traditional user. Such users purchase just under a million and a half paper charts per year from NOS. However, the requirement to produce digital data sets to support new and emerging digital marine navigation technologies has been recognized for many years nationally and internationally through such organizations as the International Maritime Organization (IMO), the Safety Of Life At Sea Convention, the International Hydrographic Organization (IHO), and the Radio Technical Commission for Maritime Services. The U.S. National Research Council's Marine Board concluded that the requirement for electronic chart data products is real and that CS must rapidly build and maintain a digital database that more efficiently generates traditional products but more importantly provides the digital data for the commercial deployment of a range of electronic

nautical chart navigation systems (Marine Board 1994). Domestically the USCG has been involved heavily in preparing for the adoption of regulations for carriage of digital nautical charts.

The range of potential digital data sets recognizes a variety of formats and content. The simplest digital chart is a raster image which can be displayed on a screen and georeferenced and overlaid with real-time navigation. The most complex and possibly powerful nautical chart digital data sets are the vector collection of nautical chart features or themes and their databased attributes so that sophisticated manipulation of these data sets can be accomplished by Electronic Chart Display and Information Systems (ECDIS). The IHO and IMO have been establishing standards and formats for such systems and data sets for several years. Unfortunately, no national hydrographic office has had success in the routine production of full vector data sets and many of them have selected the simple raster image as a more reasonable starting point to enter into the digital era.

Clearly, CS has requirements to maintain the paper nautical chart product and to develop and routinely deliver a range of digital chart data products in formats accepted by the international hydrographic community. Given these requirements, CS has a vision that by the year 2005 merchant ships, naval vessels, fishing vessels, and recreational boats will safely ply the Nation's coastal waters, electronically guided by space-based navigation and advanced digital information technologies. CS will be contributing to this revolution in U.S. marine navigation through the modernization of its nautical surveying, data management, and product generation and delivery functions. This vital support will improve the safety and efficiency of marine navigation as the nation witnesses a continual increase in vessels transits and cargo tonnage handled in U.S. ports and harbors.

MODERNIZATION ISSUES

The Office of Coast Survey and its predecessor organizations has undertaken a number of automation/modernization efforts over the last 30 years. The first effort in the mid 1960's took advantage of the minicomputer revolution initiated by Digital Equipment Corporation. This effort saw the automation of major components of the field hydrographic survey system and procedures. This HYDROPLOT-HYDROLOG system was in use with several running modifications until 1989. Attempts to automate the nautical charting production system began around 1970 with the Automated Information System (AIS) project. Tnis was a major attempt to automate existing nautical chart production procedures with the creation of large vector databases of all chart features. The concept was bold, ambitious, and premature with respect to the evolution of computer technology. The project ran for almost 15 years and resulted by 1985 in a procedure for the computer assisted "drafting" of approximately 100 charts out of the suite of one thousand. The system and project were terminated in 1988 because it could no longer be supported internally or externally.

In the mid 1980's specifications and a statement of work was developed for an Automated Nautical Charting System II (ANCS II) which was awarded to the Intergraph Corporation in September of 1988. Again this was a bold, ambitious, and conceptually elegant design which had as its centerpiece

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a vector data base of all chart features for CS' entire area of charting responsibility. The system was delivered in 1995, seven years after the project started.

In 1993, a modest effort began, supported by a NOAA-wide data capture initiative, to create raster images of the entire suite of nautical charts to be available as data sets for low-end electronic charting systems and for coastal managers and planners. This effort and the continuing development of electronic charting standards in the international hydrographic community lead CS in 1995 to prepare a modernization strategy and plan. The following objectives were identified for modernization of chart production:

1. Generate the required products - both paper and electronic.
2. Eliminate the problem of data perishability (Is the chart up-to-date?)
3. Improve product quality and utility, process efficiency, timeliness, and recognize and address any constraining paradigms
4. Replace dated source material - hydrography, topography, etc.
5. Focus on the primary customer - the commercial maritime community.

Each of these objectives is addressed below.

The need for paper and digital versions of nautical charts is well documented, with demand for each version unlikely to shift significantly in the near future. Nevertheless, there is an ongoing transition in CS and other hydrographic authorities away from a product-based orientation and toward the maintenance of a certified national database to support the generation of approved products by private partners who, in turn, make a profit delivering them to the end user. This transition represents a major change in Coast Survey's role in serving the marine navigation community.

The issue of data perishability is central and critical to the provision of a National nautical charting service. The consequence of 25 years of base erosion of program resources has caused, in recent years, a dramatic cut back in the number of new chart editions issued each year. To maintain the currency of the traditional paper chart suite for U.S. waters, nearly 400 new editions should be issued each year to deal with the accumulation of critical changes. During the past two years, personnel and financial resources have limited the number of annual new editions to between 200 and 250. The goal of the program is to keep all one thousand charts continuously up-to-date within a week of the receipt of all source data so that, in practice, a new edition of any chart could be available in real-time. This goal is one of the central objectives of the modernization plan.

Improvement of the product, process efficiency, and timeliness are also central to modernizing. The present paper chart still responds to a number of conditions, requirements, and technologies that existed more than a century ago. The nautical chart still attempts to satisfy a number of different users - the "one size fits all" paradigm. Automation and modernization should change this paradigm allowing for the potential of a variety of digital and graphic products to serve different users. The large cargo vessel steaming north in Chesapeake Bay does not care about much of the cluttered detail depicted near shore on a chart - - he needs basic information about the channel boundaries, depths

and aids-to-navigation. His requirements are different from the recreational boater. In addition, modernizing must also avoid creating redundant parallel production flows or prototype production systems which cannot be easily integrated. The various chart production procedures must be done one time only creating opportunities for what can be referred to as "two for one" or "three for one." This means that a particular production process creates by-products which in and of themselves have great value. This concept will be described more fully under the raster editing/compilation process, below.

The last two objectives listed above emphasize how CS modernization must also address the other consequences of 25 years of resource erosion and loss of field capability. This base erosion has seen the nautical charting survey fleet reduced from its zenith in 1970 of 11 major survey ships to just three in 1997, the elimination of a distributed presence in every major port in the Nation, and the reduction, as noted above, of new nautical chart editions from approximately 500/year in the late 1960's to 200/year in FY 1995. To deal with the diminishing resource base, a decision was made in 1995 to set priorities for the production of those charts which serve primarily the Nation's commercial navigation requirements in its most active ports and harbors. The concept was to reduce the overall demand on program resources so that at least the most important user would be served properly. The ranking of ports is based on a combination of total weight and value of cargo moving through these ports and harbors. Of the suite of nearly 1,000 nautical charts, approximately 200 charts which support navigation in these high priority areas will see frequent new editions of charts on regular cycles which will assure that excessive critical change does not accumulate while the other 800 charts will be produced much less frequently.

With regard to more general upgrading of the information on the nautical chart other than the critical change described above, CS is taking several steps to acquire more current data in digital form. Finally, in Budget year 1996, support from the commercial maritime community resulted in Congressional increases to the program of almost 30%. These increases are being used to contract for new hydrographic and topographic data and to upgrade the nautical charting data base and the tides and ocean circulation prediction services program as well.

THE MODERNIZATION PLAN AND STRATEGY

Coast Survey is committed to have in place by 1999 the suite of nautical charting services described below These services focus on a transition to a condition of continuous maintenance of the data from which products are generated. As noted above, continuous maintenance means that products are current (completely up-to-date) to within a week of receipt of all source data. This level of service is achievable with technology and procedures now in place which form the basis of the modernization plan. The services include but are not limited to:

Maintaining and assuring the distribution of the Nation's suite of nautical charts and nautical charting information in the appropriate formats to serve all classes of waterborne navigation users. With respect to the nautical charts, CS will be responsible for:

a. Continually maintaining digital raster chart composites of the entire suite of more than 1,000 nautical charts so that a new edition of each chart can be produced as often as weekly. The currency of these raster files will support emerging print technologies such as print on demand as well as CD-ROM technologies for distributing digital raster charts.

b. Continually maintaining digital vector chart data in the International exchange format S-57 Edition 3 to support Electronic Chart Display and Information Systems (ECDIS) so that a limited number of critical navigational themes are current to within a week of the receipt of source.

The general strategy to achieve these services involves taking advantage of automation technologies which have, in the past five years, totally changed the way the organization is doing its work. The automated tools to accomplish these goals are no longer large complicated systems but are instead truly off-the-shelf desktop computers, work stations, and software. Productivity gains are almost immediate.

The second part of the strategy is to explore and implement partnerships with private industry through contracts and cooperative agreements while still maintaining strong in-house expertise. These partnerships will provide incentives to the private sector to work with the Government to maintain the critical mix of capabilities to support the Nation's marine navigation service infrastructure.

Diagram 1 depicts the basic functional components of chart production from the receipt of source data to the delivery of products to the customer. The following descriptions explain how the functional areas and components in the diagram are being used or being developed and how they will be integrated over the next two to three years to successfully meet the requirements and vision described above.

Digital Data Sources: Source data for nautical charting comes from nearly 60 source suppliers. The most significant suppliers are the USACE (dredged project survey blue prints) and the USCG (Notices to Mariners). A major effort is underway to develop a more productive relationship with these two primary data suppliers by encouraging them to deliver digital data as opposed to hard copy. Other efforts will focus on proactively seeking source data for chart updating which has not been accessed in the past (e.g.,

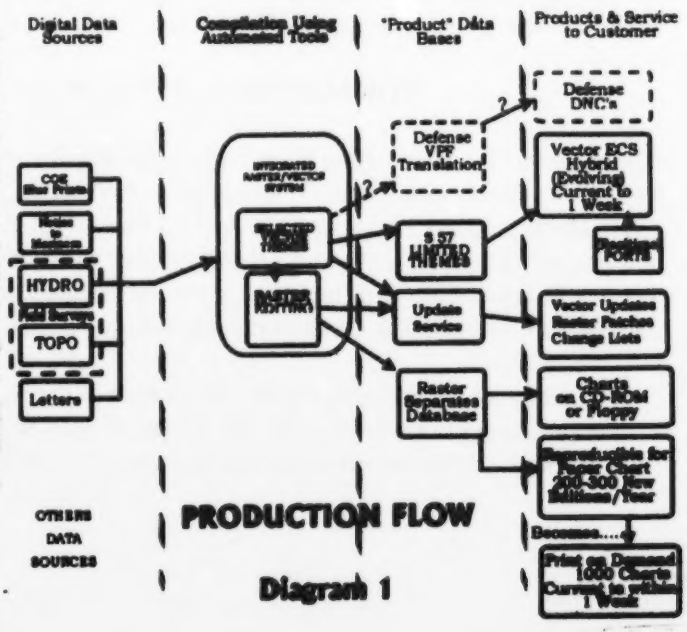

Diagram 1

large scale contract hydrographic surveys of pier faces, etc.). Receiving digital source data is crucial to the modernization of the production processes and the development of the certified nautical charting databases.

Other sources of critical charting data include CS hydrographic surveys and digital shoreline source from the National Geodetic Survey's Photogrammetry Division. In the early 1990's, CS developed a tool to estimate the location and size of the most important (or vital) areas to be surveyed. As with the New Edition priority plan, the focus of this survey prioritization tool is the commercial maritime constituency and risk of major environmental damage associated with a catastrophic grounding. Accordingly, the concept of the "Critical Area" or " Critical Requirements" was developed and they are defined as those areas where the risk of a serious marine disaster exists and where there are high priority commercial user requests for new surveys. Undue risk exists where there is a combination of high traffic volume, inadequate charts or surveys, and potentially insufficient under-keel clearances. Of the 3.4 million square nautical miles (snm) of area CS is responsible for surveying, 43,000 snm have been identified as "Critical".

Part of this survey adequacy analysis includes determining the quality of and currency of the sounding and obstruction data depicted on the charts. Of particular concern is the type of sounding technology used (lead line and single beam sonar vs. modern full bottom multibeam technologies), accumulation of uninvestigated obstructions, and changes caused by migrating shoals. Present survey capacity will complete roughly 1,300 to 1,700 snm annually, but additional requirements have tended to keep the total at a steady state. CS is purchasing state-of-the-art Shallow Water Multibeam equipment to upgrade in-house survey platforms so that the needed full bottom coverage can be accomplished in these critical areas.

Compilation Using Automated Tools: The portion of the diagram depicting "Compilation Using Automated Tools" shows the components of the automated production system now present in CS' Marine Chart Division. This portion of the diagram is the main focus of modernization.

The **Raster Editing/Compilation** component represents the rapid development and deployment of powerful raster editing tools that has allowed the production units to eliminate all manual negative engraving of nautical chart reproducibles in less than 18 months. In addition, the total time from chart compilation to product delivery has been reduced from highs of as much as 35 to 38 weeks to averages of six to eight weeks, and compilation man-hours/chart have been reduced from 200 hours to 140 hours per chart. These raster editing tools are deployed on Pentium PC platforms using a variety of off-the-shelf software including Windows NT, Microstation, and I-RAS B. All 80 cartographers doing compilation work are using these Pentium platforms for raster editing. Where possible, digital source data are brought directly into the editing environment as vector source or as scanned documents. These changes are overlaid, checked, and then "burnt" into the existing raster layer of interest to create New Editions. When digital source material is not available, manual compilation is accomplished on a plastic black line chart drawing. The drawing is scanned and again brought into the raster editing environment. Another significant advantage to this system is the ability of the cartographer to make routine improvements to the chart separate. For example, the

repeated use of the reproducible separates has caused line weights to increase to the point where some soundings and notes are almost illegible. The cartographer can easily replace eligible information on the chart using these raster editing tools.

The raster files generated by these automated tools are used to exclusively supply a private partner under a Cooperative Research and Development Agreement (CRADA) with the digital files for the manufacture and sale of the digital raster nautical charts on CD-ROM and floppy disk. The private partner has successfully completed the entire suite of one thousand charts and has on the market 21 regional CD-ROM chart suites (30 to 70 charts/CD-ROM) as well as individual charts on floppy disk. In addition, these digital raster files are used to generate the reproducibles for the 5-color press to print paper charts. The intention will be to transition from press printing of the charts (in-house or contract) to emerging print-on-demand technologies. This process is a good example of what the program refers to as a "two for one" where the raster files resulting from the editing process serve two needs - the printing requirements as well as the CRADA partner. This digital compilation technique will lead to the continuous maintenance of the entire suite of 1,000 charts so all charts in the suite will be current to within one week.

Continual Maintenance/Update Service. The data base of high resolution raster separates for the suite of one thousand nautical charts along with the highly efficient raster editing tools gives the program the ability to address one of the most critical objectives of modernization - the ability to keep all charts continuously up-to-date. The perishability of the information on a nautical chart is a major concern to the mariner. Have the aids to navigation been altered? Are there new uncharted obstructions? In the recent past, resource constraints have limited the number of new editions of nautical charts that could be issued each year. Unapplied critical change was accumulating against charts in use so that some charts required hundreds of manual Notice-to-Mariners corrections by the user to bring them up to date. A true marine navigation service with regard to charting was not being provided.

The raster compilation/editing environment along with the rapid move toward digital source data is moving each production unit toward the situation where they can keep each set of raster chart separates up-to-date with the source data as it arrives. This capability is referred to as the condition of "continual maintenance".

The movement toward continual maintenance will be lead by the establishment of a weekly chart update service. This service will give the mariner direct access to a certified data base which will contain all Notice-to-Mariners (updated from NIMA and Local, Notices) which will always be current with the publication of the NIMA weekly Notice to Mariners. The service is expected to be available electronically through several potential mechanisms including a private partner and the Internet . The update products will consist of chart specific Notice-to-Mariner change listings and raster patches. A differencing technique will be used to compare the previous week's set of raster separates for a particular chart to the newest set. The difference between the two sets of files results

in an update raster patch which can be used digitally to update a chart file or can generate a graphic patch for use with a paper chart. Again, the update service is a "by product" of the raster compilation process and can be directly accessible through a variety of electronic gateways.

Vector Electronic Chart Data - The Selected Themes Approach. As mentioned above under Requirements for Products, CS recognizes the value of vector digital data. However, creating the vector database of all charted features from high accuracy source material, and creating the various translators to convert from native system formats to the international exchange format for ENCs are extremely expensive and technically difficult problems. CS and many other hydrographic offices around the world have attempted to gather exhaustively (all features) to create standards compliant electronic nautical chart data with extremely limited success.

Realizing the value of some vector information for electronic charting, Coast Survey has reevaluated the concept of exhaustive collection and adopted an incremental strategy which seems to make the most sense technically and operationally from the point of view of the marine navigation community. This approach is illustrated clearly in Diagram 2 which shows that collecting a limited number of navigationally significant themes in vector form is a reasonable starting point in terms of cost and value to the mariner.

Given this reevaluation, Coast Survey has committed to the collection of a reduced set of navigationally significant themes which were determined through a questionnaire to the commercial marine navigation community. The concept is strongly endorsed by pilots and commercial ship operators for being particularly beneficial for collision and grounding avoidance in the close quarters harbor and port navigation environment. The reduced or limited themes data set would be compliant with the international exchange standard (S-57) except for its reduced content. The initial set of 10 themes includes:

- Aids to Navigation
- Bridges
- Anchorages
- Obstructions
- Wrecks
- Rocks
- Cables
- Traffic Separation Schemes
- Pipelines
- Platforms
- Cautionary Areas
- Dredged Areas

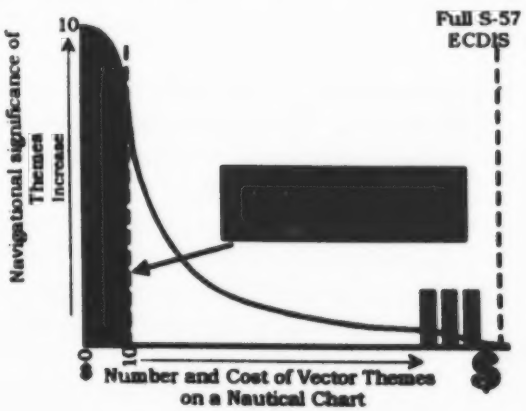

DIAGRAM 2

The concept realizes that other themes such as shoreline and other near shore information which are not included are of value, but the mariner can "marry" the digital raster chart with these selected vector themes by digital overlay, side by side display, or a separate window.

Other critical characteristics of these vector data sets include:

- Very large scale (1:2,500) where possible.
- Collection from high accuracy original source where possible.
- S-57, Edition 3 format.
- Current to within one week at all times.
- Only available as an electronic product and only available electronically.
- Expandable with other large scale data such as 1:2,500 docking charts.
- Updatable with real-time tides and currents.

These characteristics when coupled with Differential Global Positioning System (DGPS) navigation technology provides a powerful navigation tool for the commercial marine navigation community. Diagram 1, above, depicts the selected vector themes production area and how it relates to the raster editing/compilation production flow.

The **"Product" Databases** depicted in Diagram 1 create opportunities for CS to actually move away from the orientation of creating a final product and more toward the development of relationships with chart agents and service providers for the creation of the nautical chart products both digital and paper by the private sector in accordance with standards. Print-on-demand technology is nearly at a point where these types of relationships can be established. The infrastructure for routine transmission of digital data is already here. Although the paper chart will be in use for the foreseeable future even while these new electronic systems and data sets are rapidly evolving and being deployed, the classic printing process is expected to be eliminated in the near term. Users will be able to download and print the latest edition of a chart or the latest raster correction patches and avoid the data perishability issue which results from the old way of doing business.

CONCLUSION

Modernization of the nautical charting data production activity in CS involves two automation efforts -- raster editing / compilation and selected theme vector electronic chart data sets. The raster editing / compilation process is the "engine" that drives CS' chart production program. It was developed rapidly (18 months) in an "ad hoc" fashion with in-house personnel and truly off-the-shelf PC hardware and software. Productivity gains and new product opportunities appeared almost immediately. CS is taking an incremental approach to building a vector electronic chart product, collecting data for the most important themes first. This will provide "intelligent" data which the mariner can use in conjunction with a raster chart display system.

These two automation efforts are giving CS' nautical charting program the capability of meeting in the very near future all modernization objectives and achieving the overall goal of eliminating redundant / parallel production flows.

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REVIEW OF THE LATEST TECHNOLOGY IN CARTOGRAPHIC DATA ACQUISITION, MANIPULATION, STORAGE AND PRESENTATION, WITH SPECIAL EMPHASIS ON POTENTIAL APPLICATIONS IN DEVELOPING COUNTRIES: GEOGRAPHIC INFORMATION SYSTEMS: DEFINITION, FORMATION AND APPLICATION

The United States National Spatial Data Infrastructure

Paper submitted by the United States of America**

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INTRODUCTION

Over the past few decades such tools as satellite remote sensing equipment, global positioning systems, map digitizing and scanning equipment, image processing software, geographic information systems, and digital map printing systems, have allowed governmental and private sector organizations to collect, analyze, and manage electronic information related to geographic location in a way never possible before. As the technology has evolved, the value of spatial analysis has been increasingly recognized as an aid to understanding environmental and social issues that are often closely related to geographic location. These tools can integrate many different themes of data, and their usefulness has resulted in an expanded base of users.

As the user base has grown, so has the complexity of the environmental, economic and social questions being asked. The production of geographic data is burgeoning. Geographic data are now being produced by thousands of organizations in the public and private sectors. Even though many different data sets are being produced over many different geographic areas at many different levels of resolution, there are few organizations with the resources to produce and maintain all the data they need to take full advantage of these new technologies.

Since many organizations may produce and maintain geographic data about the same location, data might conceivably be shared between and among organizations, allowing organizations to direct their resources into problem solving rather than data collection. As part of a movement to streamline government operations and better manage resources, the concept of geographic data as a shared basic infrastructure to support complex decision making has lead to the development of the National Spatial Data Infrastructure (NSDI). The NSDI, as established by Executive Order in 1994, is defined as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of geospatial data." (Executive Office of the President 1994)

THE CONCEPT OF THE NATIONAL SPATIAL DATA INFRASTRUCTURE

Historially organizations that used GIS developed a "stovepipe" approach to problem solving. Separate organizations, or even separate parts of the same organization, would collect different themes of data using different combinations of software and hardware for unique applications. Information was seldom shared across organizational lines. It became increasingly clear that this approach was inefficient and did not take advantage of the integrating capabilities of GIS that allow many attributes and themes of data to be registered to one geographic location. Agencies began to

realize the value of developing a more open approach in which data that are commonly used can be shared within an organization and exchanged with groups outside the organization. For example, a county planning department, a highway department, and a tax office may each develop and maintain separate street center-line data bases. A more efficient arrangement would allow one street file to be shared among departments. This requires defining which of the three offices is responsible for updates and maintenance. Emphasis is placed on developing working relationships between and among the participants and developing standards that enable data sharing rather than on unique data collection.

This approach builds on the concept that geographic space can serve as a common denominator for problem solving. Sharing data can result in efficiencies in data development and responds to current organizational changes such as corporate "downsizing," the devolution of authority towards flatter organizational structures, and an interest in partnerships. Such an approach can create the multifaceted collections of knowledge needed to cooperatively tackle complex issues such as regional transportation planning or community sustainability.

The Federal Government, to encourage data sharing partnerships, made NSDI a major part of its effort to improve the way in which services are delivered to its citizens. A September 1993 report stated that "In partnership with state and local governments and private companies we will create a National Spatial Data Infrastructure." (Gore 1993) Implementation of the NSDI was effected through the issuance of Executive Order 12906 in April 1994. This order directs Federal agencies and the Federal Geographic Data Committee (FGDC), an interagency coordinating body, to provide federal leadership in the development of the NSDI.

ACTIVITIES TO DEVELOP THE NSDI

Initial activities to implement the NSDI concentrated on standards development, data sharing through clearinghouses, and shared production responsibilities for certain basic framework themes of data. These priorities were established through a series of public meetings of individuals from the public and private sectors and are outlined in the "1994 Plan for the National Spatial Data Infrastructure" (Federal Geographic Data Committee, 1994a) and in the Executive Order. The 1994 plan was recently updated and reissued as "A Strategy for the national Spatial Data Infrastructure (Federal Geographic Data Committee, 1997)."

Standards

Data sharing requires standards. Standards are most effective when they voluntarily emerge from wide acceptance and use within a community. Any standards process must take into account not only technical issues, but institutional, economic and behavioral issues. Standards development can often be contentious. Within the FGDC the Standards Working Group facilitates the overall process within which standards are developed by any of a dozen thematic subcommittees. Each subcommittee develops standards for data collection and content, data presentation, and data management for a

particular theme of data such as transportation, vegetation, cadastral or soils. Standards undergo extensive nationwide public review and revision that encompasses comment and testing phases and solicits input from state and local government agencies, private sector firms, and professional societies. The process may be time consuming but it increases the likelihood that standards will be used throughout the community. To date, a metadata standard has been developed and adopted in 1994; cadastral standards and a wetlands classification standard were adopted in 1996; and several standards are undergoing national review. These include a Soil Geographic Data Standard, Geospatial Positioning Accuracy Standards, and Content Standards for Digital Orthoimagery and Elevation Data.

Clearinghouse

The National Geospatial Data Clearinghouse links people seeking data with data producers. The clearinghouse is decentralized; that is data are maintained locally while information about where data can be obtained is shared through electronic networks. Potentially millions of data holdings in many different geographic locations will be cataloged and accessed through the clearinghouse.

Three elements are necessary to operate a distributed clearinghouse. Metadata, or "data about data" provides information in a data transfer and is essential to the clearinghouse concept because it serves as a catalog entry for data when made accessible on the Internet. The Content Standards for Digital Geospatial Metadata (Federal Geographic Data Committee, 1994b) establishes a consistent means to describe the quality and characteristics of spatial data. The Executive Order mandated that all Federal agencies use the standard to document new spatial data sets created after January 1995. Data producers from other levels of government, as well as the private sector, are being encouraged to use the standard to describe their data.

The second required element of the clearinghouse is the Internet. As the "network of networks" linking millions of people globally, it provides users with the ability to retrieve metadata descriptions of data sets held by data producers. Some data producers may also put the data online for downloading. Federal agencies and other organizations are being encouraged to use the Internet to provide access to metadata descriptions of their data holdings.

The third requirement in implementing the clearinghouse is the use of software tools for searching and querying data on the network. "Browsers" allow users to access "home pages" on the World-Wide Web, a graphical protocol for displaying information on the Internet by means of hypertext links. Many organizations are sharing both metadata descriptions and data by allowing users to browse their World-Wide Web sites. The FGDC is supporting the development and enhancement of searching software and the refinement of a search engine based on ISO 10163 (ANSI Z39.50) an international standard maintained by the library community, that specifies how an information search is expressed. This standard will allow for structured spatial searching of many different servers on the Internet for metadata. Current research is also underway to develop intuitive graphical map-based interfaces for searching and displaying the geographic locations and other characteristics of metadata.

Most Federal agencies and many state and local governments are currently disseminating data through sites on the Internet. Many thousands of files a month are being accessed in this manner, saving the cost of mailing maps or computer tapes. The U.S. Fish and Wildlife Service reported that in the first month of operation, approximately 29,000 digital maps from the National Wetlands Inventory were retrieved. The U.S. Geological shared 40,000 digital files with its customers during the first three months it had established an Internet presence. (Federal Geographic Data Committee, 1994c)

Framework

This activity is attempting to develop a framework of commonly-used themes of data based on shared responsibility for data creation and maintenance. These themes include digital orthoimagery, geodetic control, elevation, transportation, hydrography, governmental boundaries, and cadastral or ownership information. The framework will provide a current base on which to collect, register, or integrate other data sets for analysis. Although framework data often will only be used to support other applications, many organizations spend time and money digitizing or seeking these data sets. A common approach to building and maintaining these data sets could free an organization's resources for more pressing applications.

A Framework Working Group was formed by the FGDC in 1994 to study how to prototype the framework activity. This group consisted of representatives of Federal, state, and local government agencies. They proposed linking various existing data collection activities over specific geographic areas, recognizing that, in most instances, local governments are collecting the highest resolution data and have the most at stake in keeping their data current (Federal Geographic Data Committee 1995). Local organizations thus will play a critical role in the development and maintenance of framework data. The framework approach will allow state and Federal agencies, through collaboration with local governments, to obtain data that is more current and accurate than they would be able to create themselves.

A series of pilot studies is underway to test the assumptions of the group's report. These studies will help identify institutional issues, develop standards, possible funding initiatives, and operational guidelines for developing framework data.

ENCOURAGING PARTICIPATION IN THE NSDI

Promoting the idea of data sharing and collaboration among a diverse and widely spread set of organizations has been one of the FGDC's primary challenges. Political support from the President's Office of Management and Budget and the willingness of the Secretary of the Interior to chair the FGDC have provided a mandate and political visibility to the effort. The Secretary's involvement, in particular, has encouraged other Federal agencies to commit resources at high political levels, and has persuaded many state and local governments to elevate local needs for spatial data production and coordination. National attention has also hastened the use of standards and improved data accessibility.

The FGDC has structured its activities to allow participation by non-Federal organizations in ongoing development of the NSDI. Some of the initiatives to broaden participation are:

- Establishing coordinating groups with interest in a particular geographic area. Many states have geographic information councils that cross institutional and organizational boundaries because of their concern for solving local problems. Such councils can be important allies in the development of standards and for outreach on data sharing issues. The FGDC has a formal program to recognize these councils as partners in the development of the NSDI. Fifteen councils have been recognized thus far and many have participated in meetings with the FGDC.

- The FGDC established a Competitive Cooperative Agreements Program to encourage participation and experimentation in the development of the NSDI. These agreements are funded through an annual competitive process. Participants support collaborative activities on metadata implementation, data clearinghouse development, framework data, standards development and implementation, and other issues. A total of 62 cooperators from state and local governments, non-profit organizations, academic institutions, and private industry have been funded in the three years since this program began.

- The FGDC conducts numerous training courses, workshops and presentations about its activities at national, state, regional and user group conferences. The FGDC and its various subcommittees publish a newsletter and several technical reports each year. These can be accessed electronically from the FGDC home page on the World-Wide Web <http://www.fgdc.gov>

FUTURE EVOLUTION OF THE NSDI

The NSDI is constantly evolving as telecommunications and GIS technologies change. Thus, predicting the future is difficult. Institutional, social, and economic issues will play a large role in future directions. Some of the questions that will certainly impact the future of the NSDI are listed below:

Economic and institutional:

- What are the implications of cost-recovery policies on the evolution of the NSDI, and how will the imposition of such fees impact the availability and quality of spatial data?
- Should copyright be applied to spatial data?
- What should be the data collection and maintenance roles of federal, state, and local agencies over a given piece of geography, and how do these relate to private sector initiatives?
- What incentives will promote interagency coordination; what are the constraints?
- What mechanism, if any, is required to oversee the NSDI?

Standards:

- What standards will promote data sharing?

- How are standards best created? By the federal government? The private sector?
- Who should be responsible for maintaining standards?
- What mechanisms or incentives will encourage the use of standards?
- Is the concept of a "certified" data set useful, and, if so, who would certify?

Technical issues

- How can different data sets from different computers be used across a distributed network?
- What is the best way to promote interoperability? Through transfer standards? Data structure specifications? And what roles and incentives are there for the private sector?
- How can multiresolution data sets collected by different organizations best be integrated and used?
- Who defines features and on what basis?
- What is the best way to represent metadata to the end user?

CONCLUSION

Efforts so far to develop the NSDI have focused on very specific problems such as: Who has what data? How can data sets be accessed? Are these data suitable for my application? Future efforts will depend on the community's ability to agree on many institutional, policy, economic and technical issues. These challenges will only be overcome and the NSDI developed through the creation of partnerships, placing responsibility for data creation at local levels, and collaborating to resolve issues.

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1 April 1997

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SIXTH UNITED NATIONS REGIONAL
CARTOGRAPHIC CONFERENCE FOR
THE AMERICAS
New York, 2-6 June 1997
Item 5 (b) of the provisional agenda*

REVIEW OF THE LATEST TECHNOLOGY IN CARTOGRAPHIC DATA ACQUISITION, MANIPULATION, STORAGE AND PRESENTATION, WITH SPECIAL EMPHASIS ON POTENTIAL APPLICATIONS IN DEVELOPING COUNTRIES: GEOGRAPHIC INFORMATION SYSTEMS: DEFINITION, FORMATION AND APPLICATION

Standards for the Global Spatial Data Infrastructure (GSDI)

Paper submitted by the United States of America**

* E/CONF.90/1.

** Prepared by Henry Tom, National Imagery and Mapping Agency.

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INTRODUCTION

Over the past two decades, the introduction of computers to the geographic community has progressed from the automation of manual techniques in cartography to the analysis of spatial data by geographic information systems (GIS). A GIS is an information system which answers the fundamental question of where? In general, geographic information systems organize, analyze, and display spatial data. Beyond producing computer maps, a GIS performs spatial analysis and complex queries. GIS serves as an enabling technology because so much data is inherently spatial through geo-referencing by a coordinate system or set of alphanumeric codes.

The integration of technological advances in computer hardware and software capabilities with mapping and analytical functionality in conjunction with decreasing costs have led to rapid rise and use of GIS technology. GIS capabilities are beginning to be integrated into mainstream information technologies. For example, within the context of a spreadsheet application containing data associated with numerous cities within a country, a simple function would be to selectively display their locations on a map as an option. Portable Global Positioning Systems (GPS) receivers record geographic locations from anywhere on the earth and are used in surveying, mapping, and navigation systems for land vehicles, planes, and ships. The geographic community has invested considerable resources into the conversion of analog spatial data, such as paper maps, into digital form. Satellites, using a variety of sensors, will provide a new and abundant source of spatial data. Optical and radar satellite imagery are important for updating maps and/or originating digital spatial databases Such systems will provide terabytes of spatial data in digital form directly, without the lengthy and costly process of analog to digital conversion, to the geographic community and the information technologies incorporating GIS functionality.

Currently, the declining cost of producing and using spatial data is intensifying the need to share and integrate spatial data. Hence, the availability, accessibility, management, and integration of digital spatial data is becoming a major challenge to the GIS community of data producers, software vendors, systems integrators, and users. Increasingly, the international response to this challenge is the formation of spatial data infrastructures.

Spatial Data Infrastructures

Spatial data infrastructures (SDI) at the national and regional levels are collectively stimulating the emergence of the global spatial data infrastructure. A spatial data infrastructure for a country is considered a national spatial data infrastructure (NSDI), which can vary by country. A regional spatial data infrastructure (RSDI) is comprised of several NSDIs or by a number of countries, in which a country may or may not have its own NSDI. Accordingly, the global spatial data infrastructure is formed by linking national and regional spatial data infrastructures.

Four elements are emerging as major components of a spatial data infrastructure, common to each level of the global spatial data infrastructure. The four components are: ***technology, standards, policy, and institutional framework***. For technology: there was acknowledgment that GIS technology is founded upon generic information technology, which accentuates the need for GIS technology to be fully integrated with the emerging Global Information Infrastructure (GII). For standards: GIS standards are also based on information technology standards and that the GIS standards infrastructure needs to be understood, adopted, and utilized within the broader structure of a spatial data infrastructure. For policy: many policies need to be developed, with an international viewpoint, regarding all aspects of data. For institutional framework: agreements must be ratified for coordinating the formation and linking of national and regional spatial data infrastructures to form the global spatial data infrastructure.

Another important aspect of the global spatial data infrastructure is the concept of ***framework data***. Framework data are those basic datasets upon which most other datasets could be built. Some of the basic datasets identified include: geodetic, cadastral, hydrography, transportation, boundaries, elevation, and digital orthoimagery datasets. It was quite apparent that the underlying dataset for framework data is the *geodetic network*, which provides consistent global geo-referencing for spatial datasets created or derived.

Internationally, there is consensus in recognizing the importance of GIS standards. The correspondence of levels between the GIS standards infrastructure and those of the global spatial data infrastructure facilitates the integration of spatial data. GIS standards can integrate horizontally across a spatial data infrastructure level and vertically integrate between various levels. GIS standards provide the horizontal integration of spatial data at each of the federal government, municipal, county, and state levels and provide the vertical integration of these levels to form the national spatial data infrastructure. Similarly, GIS standards also provide the horizontal integration of spatial data across each of the national and regional levels, while providing the vertical integration of these levels to form the global spatial data infrastructure. Equally significant, the global spatial data infrastructure serves a major role in the development, deployment, and implementation of international GIS standards. The success of standards, in turn, determines the viability of the global spatial data infrastructure. Consequently, a basic understanding of GIS standards and the GIS standards infrastructure is vital.

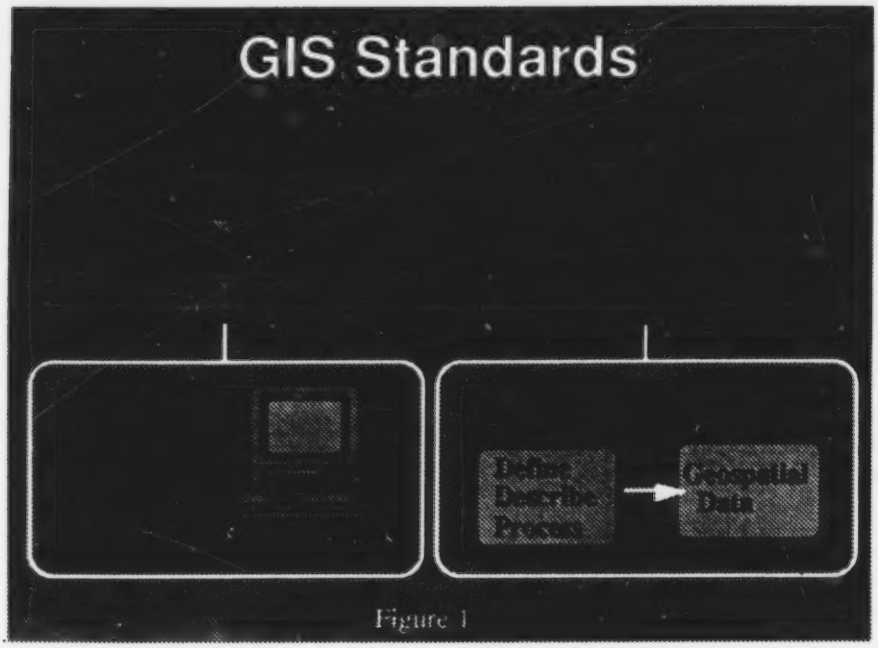


Figure 1

GIS Standards

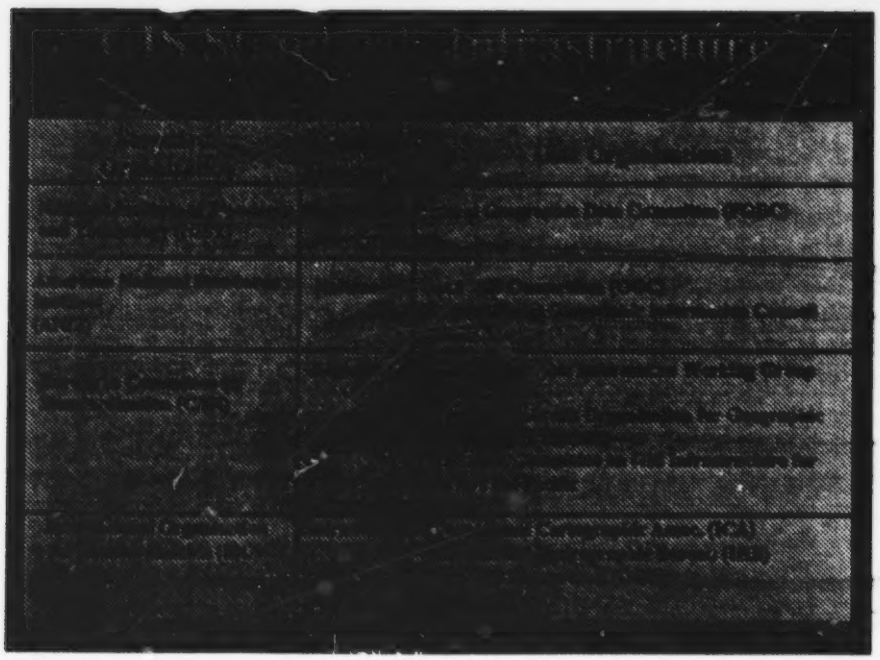
GIS standards are comprised of both information technology standards and spatial data standards. Information technology standards are either adopted in total or adapted with modification. Spatial data standards are developed to define, describe, or process spatial data. (Figure 1) During the past decade, GIS standardization was focused on developing a spatial data interchange standard. This effort, however, was made by over two dozen countries and international organizations. As a result, several spatial data interchange standards exist. Because this was the first standardization effort within the GIS world, it required a long time to overcome an atmosphere of reluctance and to establish a mindset receptive to standardization within the GIS community. This change in attitude is the true value of these initial efforts in standardization. The GIS community is now accepting standards, such as the forthcoming metadata standard. In conjunction with this acceptance, three trends in GIS standardization have evolved.

First, the development of GIS standards should be anticipatory. Standards developed as a reaction to a problem are usually too late because of the lengthy development time and equally long if not longer time required for approval. The time span required for approval generally reflects the extent of consensus needed. If standardization occurs too late, resistance from established providers and users can derail any coherent resolutions. Timing in standardization is critical. If standardization occurs too soon, it can stifle innovation or even lead technology away from its own course of evolution. Effective standardization requires foresight and begins before the needs and problems arise.

Secondly, the development of GIS standards now includes the participation of end users. GIS users are not only concerned about the interoperability of hardware and software, they are specifically addressing the interoperability of data - in terms of terminology, syntax, and semantics. GIS users, having reached a level of maturity and sophistication, are aware that many of the spatial data standards to be developed, in large part, will be implemented and used by GIS data producers and users.

Thirdly, GIS standards need to be integrated. The GIS community recognizes that standards will be used more as an integrated set of standards than just a number of stand alone standards. Several emerging standards such as the metadata standard and data quality standard will be incorporated as parts of other forthcoming standards.

Globally, the development of GIS standards is occurring at government, national, regional and international levels. This development is not confined to just standards organizations which formally develop and approve standards. Substantial efforts are being made in various user/applications communities. Some user/applications communities may develop standards, while others endorse and/or adopt GIS standards. These communities are, in fact, the user community for GIS standards. There is a definite need to coordinate this development from the standpoints of integration and division of labor to avoid duplication and incompatibility. Collectively, these organizations and efforts form the GIS standards infrastructure which needs to be understood and incorporated into the hierarchy of spatial data infrastructures.



The GIS Standards / Spatial Data Infrastructures

The GIS standards infrastructure, a specific subset of the global standards infrastructure, provides an institutional structure and process for coordinating and integrating the development of GIS standards. The levels of the GIS standards infrastructure correspond with the global spatial data infrastructure. This correspondence in levels reflects common coverage in organizational jurisdiction and applicability. At the government and national levels, there will be some variation depending on the political and cultural composition of a particular country. The term regional, in the context of the GIS standards infrastructure and the global spatial data infrastructure, applies to a grouping of countries. Regional can also be applied to a grouping of cities, counties, and provinces - depending on the country and its composition. By example, the following is a description of the GIS standards infrastructure primarily from the perspective of the United States of America. (Figure 2)

National Level

For the United States of America, standardization efforts occur at the state government, federal government, national, and international levels - standardization at the local level is incorporated under the state level. (Figure 3) At each level of the GIS standards infrastructure, there can be two types of organizations developing standards: formal standards bodies and user/industry organizations.

Within the United States, standards efforts at the city and county levels form tiers under the state level. These efforts are either formal or user/industry based. States in the US are generally influenced by the activities of other states, associations of states, and primarily, the federal government.

At the U.S. federal government level, the National Institute of Standards and Technology (NIST) promulgates standards for organizations within the federal government. NIST is a formal standards body. The Federal Geographic Data Committee (FGDC) is the primary user group at the federal government level. The FGDC is composed of federal organizations which have a primary interest and activities involving spatial data. In 1994, FGDC was given a mandate to initiate the development of spatial data standards. FGDC has approved the Spatial Data Transfer Standard (SDTS) and its Topological Vector Profile (TVP) and developed the Metadata Standard. FGDC has been quite active and as of September 1996, two standards have completed the public review stage, four standards are either in preparation or out for public review, ten standards in draft, and five proposed standards. (Appendix A)

At the U.S. national level, this consists of the federal and state governments, public, private, academic and professional communities. The formal standards body at this level is the American National Standards Institute (ANSI) accredited X3L1, GIS technical committee. At the national level, user/industry groups include the Open GIS Consortium

(OGC), National States Geographic Information Council (NSGIC), and also the Federal Geographic Data Committee. NSGIC is a council composed of the state GIS coordinator or equivalent for almost all the states in the US. The OGC is a consortium of vendors, integrators, researchers, government agencies, data suppliers, and users. The objective of OGC is to share spatial data and geoprocessing functionality through middleware (software) within a distributed computing environment. The OGC is currently developing the Open Geodata Interoperability Specification (OGIS). When completed, it will be submitted to the formal standards environment for approval as a standard. All participants at the national level contribute to the formal process of GIS standardization through X3L1. X3L1 also serves as the US Technical Advisory Group (TAG) to the recently formed International Organization for Standardization (ISO) Technical Committee 211, Geographic Information/Geomatics.

GIS Standards/Spatia Data Infrastructure

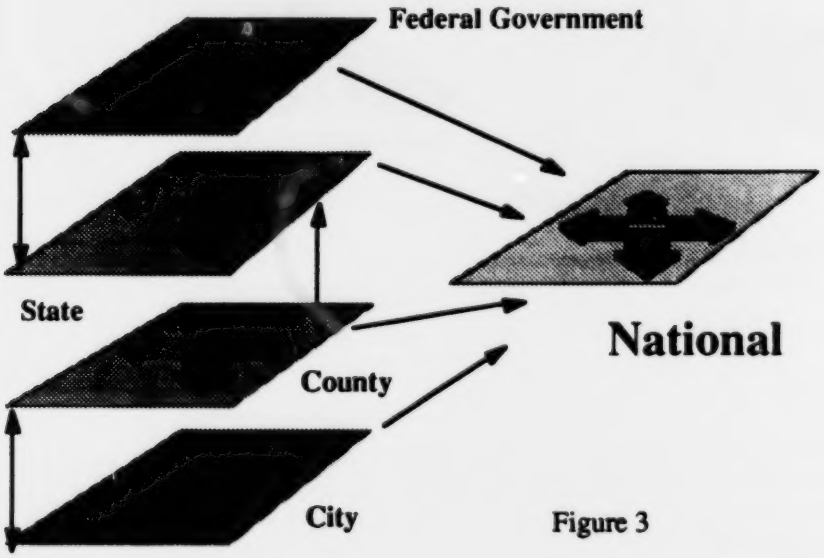


Figure 3

A national spatial data infrastructure formalizes the structure and process for organizing, using and sharing spatial data common to a broad spectrum of applications and users within a country. The concept of a spatial data infrastructure is not new. The need was recognized several years ago. In 1990, the Federal Geographic Data Committee (FGDC) in the United States of America began such an initiative. This effort received substantial visibility when President Clinton issued Executive Order 12906, April 11, 1994 to formally establish the National Spatial Data Infrastructures (NSDI) and the Secretary of the Interior, a member of the President's Cabinet, personally chaired the FGDC. Other countries such a Canada, the United Kingdom, Australia, Japan and Korea, have also established their own NSDI during the past two years. In Chile, the First International Symposium on Spatial Databases of Immediate Access, Oriented to Multi-Users and Multiple Applications was held from October 29-31, 1996 in Valparaiso, Chile. The

third day of this meeting was devoted to exploring proposals and possibilities in achieving a global spatial data infrastructure. The resulting proposal is one supporting the development of a national spatial data infrastructure. A robust national level within the GIS standards infrastructure enhances the integration of spatial data across a national spatial data infrastructure while providing the integration paths to a regional and/or global spatial data infrastructure.

GIS Standards/Spatia Data Infrastructure

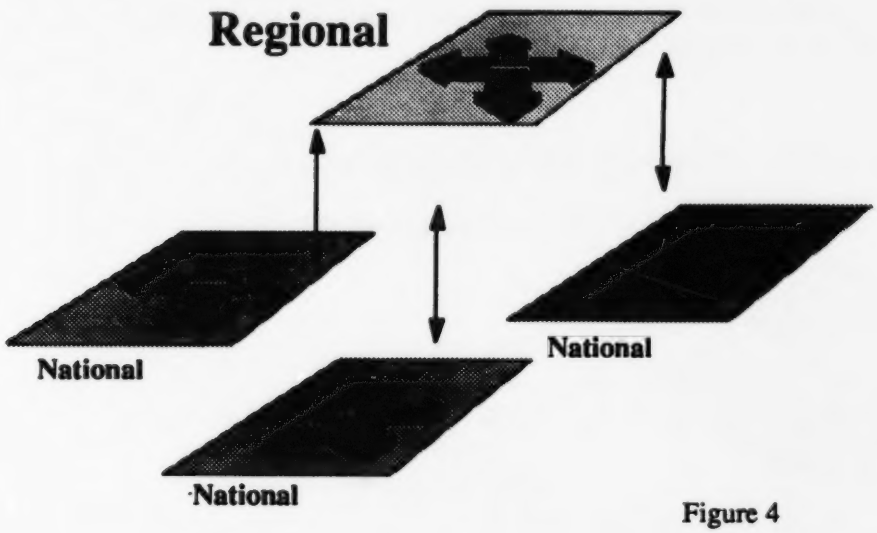


Figure 4

Regional Level

Although the United States does not include a regional level (group of countries), the regional level for European and the Asia and Pacific countries is quite significant. Thus, depending on the region of the world, levels for the GIS standards infrastructure will vary accordingly. (Figure 4)

In terms of a regional level within the GIS standards infrastructure, Europe has a formal regional standardization body. The European Committee for Standardization (CEN) is very active with two technical committees having direct relevance to GIS standards, CEN/TC 278, Road Informatics and CEN/287, Geographic Information. The major user group is EUROGI, which serves as the umbrella organization for 16 national geographic information associations, six pan European organizations, and includes a number of observers. The European community, under the leadership of the European Umbrella Organization for Geographic Information (EUROGI), established the European Geographic Information Infrastructure (EGII), while the Permanent Committee on GIS Infrastructure for Asia and the Pacific was formed recently. Although the Asia/Pacific regional standards body is not currently engaged in GIS standards, this may not be

necessary. The Permanent Committee on GIS Infrastructure for Asia and the Pacific, the primary user group for this region, may adopt GIS standards directly from ISO/TC 211. The directors of national surveying and mapping organizations for over 55 countries were invited to attend the meeting in Sydney, Australia from September 29 - October 4, 1996. The Permanent Committee was formed as a result of a resolution passed at the Thirteenth United Nations Cartographic Conference for Asia and the Pacific in Beijing, China in May 1994. The Permanent Committee has made progress in approving the Statutes and Rules of Procedure and the organization of the following working groups and their work plans:

WG1 Geographical Information Infrastructure and Institutional Framework
WG2 Issues relating to Cadastral Infrastructure
WG3 Regional Geodetic Networks
WG4 Legislation and administrative arrangements for the acquisition and sharing of spatial data.

Both the European and Asia / Pacific regional spatial data infrastructures are converging in their consensus that the work of ISO/TC 211 may provide the GIS standards to enable the global spatial data infrastructure. Also, there was an overall agreement on the need to cooperate and coordinate on issues requiring further study and resolution. At these international meetings, the global sharing of spatial data was deemed essential - providing international benefits which contribute to improving the quality of life and preservation of the global environment. The focus in the European region was data sharing, while in the Asia and the Pacific region, it was technology transfer.

International Level

At the international level, ISO is the formal standards body. There are more than 100 member countries in ISO. Each country has a national standards organization which represents them in ISO. Depending on interest in a technical committee, each national standards body designates a Technical Advisory Group (TAG) to represent the national body within the technical committee. Each country has only one vote. Liaison members to an ISO technical committee may receive technical documents and participate at meetings, however, liaison members may not vote. National body members with an observer status may vote in letter ballots.

User/applications groups at the international level include: International Cartographic Association (ICA), International Hydrographic Bureau, and the International Society for Photogrammetry and Remote Sensing (ISPRS). Because OGC now has memberships from various countries, it can also be considered as an international user organization.

In April, 1994, ISO/TC 211, Geographic Information/Geomatics was established and held its first plenary meeting during November, 1994 in Oslo, Norway. There are twenty-four members and thirteen observing members. From the user perspective, ISO/TC 211 has nine Class A liaisons with international organizations, as well as seven other ISO technical committees. Many of the GIS standards required for spatial data infrastructure, at all levels, are currently being developed by this committee.

The Secretariat of ISO/TC 211 is Norway and the Chairman is Mr. Olaf Ostensen. The current programme of work includes twenty work items which will become standards. The ISO standard identified for this work is ISO 15046, parts 1-20 with completion slated for 1998. (Appendix B) While the programme of work for ISO/TC 211 is substantial and broad, the real measure of success will be whether or not these standards can function as an integrated set of standards. The success of the global spatial data infrastructure is directly dependent upon the GIS standards infrastructure and its international component, ISO/TC 211.

Recently, EUROGI and other leading geographic organizations such as the Atlantic Research Institute, Institute for Land Information (ILI), Deutscher Dachverband fur Geoinformation, Open GIS Consortium, FGDC, and Commission 3, Federation Internationales des Geometres (FIG) under the sponsorship of the European Commissioner, Mr. Martin Bangemann, held a meeting from September 4-6, 1996 in Bonn, Germany to initiate a dialogue on the Emerging Global Spatial Data Infrastructure. There was consensus on the need for a common vision, vocabulary, and an international forum to coordinate such efforts. The meeting was attended by representatives from twenty countries primarily from the European region. (Figure 5)

GIS Standards/Spatia Data Infrastructure

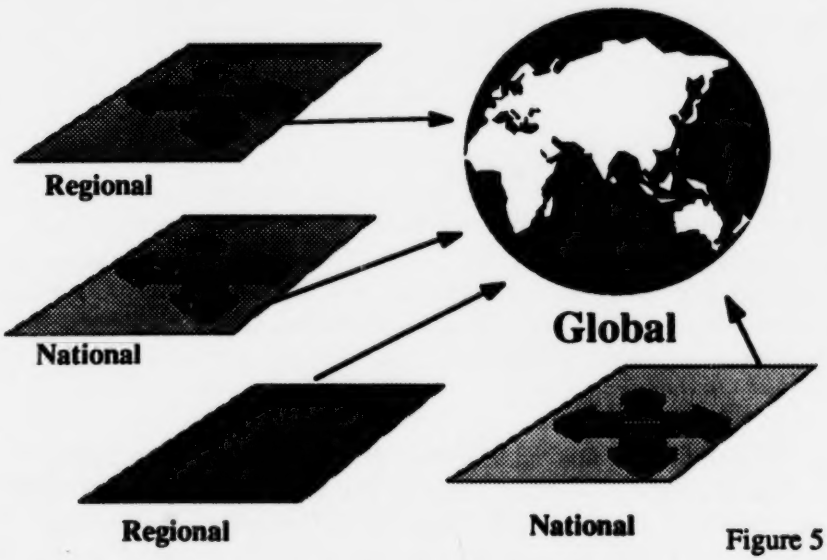


Figure 5

Conclusion

As envisioned, the global spatial data infrastructure has four components to enable its realization: technology, standards, policy, and institutional framework. With standards as a major component, the GIS standards infrastructure is established with a well-defined structure and process. Incorporating the GIS standards infrastructure within the global spatial data infrastructure provides much of the needed integration for spatial data.

Standards for the global spatial data infrastructure represents a rare opportunity to truly make a difference - globally. Many developing countries not currently participating in ISO work may now take an active role. This is because standards and the participation in developing standards is a mechanism for technology transfer. GIS technology is also fundamental for much of the infrastructure development projects in developing regions of the world. Successful regional integration of enabling information technologies such as GIS technology will depend, in no small part, on availability and acceptance of standards.

Appendix A -

Status of U.S. Federal Geographic Data Committee (FGDC) Standards

September, 1996

Approved

Spatial Data Transfer Standard (SDTS)
Spatial Data Transfer Standard (TVP) Topological Vector Profile
Content Standard for Digital Geospatial Metadata

Completed Public Review

Cadastral Data Content Standard
Classification of Wetlands and Deep Water Habitats

Out for Public Review

Vegetation Classification Standard

In preparation for Public Review

Soils Geographic Data Standard
Geodetic Control Networks Accuracy Standard
National Spatial Data Accuracy Standard

Standards in Draft

Standards for Digital Orthoimagery
Standards for Digital Elevation Data
Transportation Network Profile for SDTS
Specification for Encoding a Linear Referencing System
Point Profile for SDTS
Transportation Spatial Data Dictionary
River Reach Coding Standards
Metadata Profile for Cultural and Demographic Data

Geospatial Positioning Accuracy Standards
Digital Geospatial Metadata Standards for Geodetic Data

Proposed Standards

Cartographic and Digital Standards for Geologic Data
Utilities Data Content Standard
Geospatial Environmental Hazards Standard
Facility Identification Data Standard
CADD Profile for SDTS

Appendix B -

Overview of ISO/TC 211, Geographic Information / Geomatics

Scope:

Standardization in the field of digital geographic information. This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. This work shall link to appropriate standards for information technology and data where possible, and provide a framework for the development of sector-specific applications using geographic data.

Members:

P - Members (24)

Australia	*Republic of Korea*
Austria	*Morocco*
Canada	*The Netherlands*
China	*New Zealand*
Czech Republic	*Norway*
Finland	*The Russian Federation*
France	*South Africa*
Germany	*Spain*
Iran	*Sweden*
Italy	*Turkey*
Jamaica	*United Kingdom*
Japan	*United States of America*

Observers:

O - Members (13)

Belgium	*Pakistan*
Denmark	*Poland*
Hong Kong	*Portugal*
Hungary	*Switzerland*
Iceland	*Ukraine*
India	*"Yugoslavia" **
Malaysia	

* "Serbia and Montenegro have asserted the formation of a joint independent state, but this entity has not been formally recognized as a state by the United States. The United States view is that the Socialist

Federal Republic of Yugoslavia (SFRY) has dissolved and that none of the successor republics represents its continuation.

Class A Liaisons (9):

Digital Geographic Information Working Group (DGIWG)
European Petroleum Survey Group (EPSG)
International Association of Geodesy (IAG)
International Cartographic Association (ICA)
International Federation of Surveyors (FIG)
International Hydrographic Bureau (IHB)
International Society of Photogrammetry and Remote Sensing (ISPRS)
Open GIS Consortium (OGC)
United Nations Economic Commission for Europe (UNECE)

Internal Liaison (7):

ISO/TC 46/WG2	*Information and Documentation*
	Coding of country names and related entities
ISO/TC 82	*Mining*
ISO/TC 184/SC4	*Industrial Automation Systems and Integration*
ISO/TC 204	*Transport Information and Control Systems*
ISO/IEC/JTC 1/SC21/WG 3	*OSI, Data Management and ODP*
ISO/IEC/JTC 1/SC 30	*Open EDI*
ISO/IEC/JTC 1/SWG GII	*Global Information Infrastructure*

ISO/TC 211 work groups and work items:

WG 1, Framework and Reference Model - Convenor, United States of America

Reference Model
Overview
Conceptual Schema Language
Terminology
Conformance and Testing

WG 2, Geospatial Data Models and Spatial Operators - Convenor, Australia

Spatial Subschema
Temporal Subschema
Rules for Applications Schema
Spatial Operators

WG 3, Geospatial Data Administration - Convenor, United Kingdom

Cataloguing
Geodetic Reference Systems
Indirect Reference Systems
Quality
Quality Evaluation Procedures
Metadata

WG 4, Geospatial Services - Convenor, Norway

Positioning Services
Portrayal of Geographic Information

Encoding
Services

WG 5, Profiles and Functional Standards - Convenor, Canada

Profiles

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A geographic data framework for economic development

Paper submitted by the International Cartographic Association**

* E/CONF.90/1.

** Prepared by John A. Kelmelis, United States Geological Survey.

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Abstract

For long-term economic well-being, it is important to make rational use of the best technologies available for resource management. Although these technologies will not be sufficient in themselves to ensure long-term sustainable prosperity, they can help reduce natural resource degradation and minimize its impact. This can "buy time" while national and international governing bodies take the appropriate steps to bring about behavioral changes that will result in stewardship rather than exploitation of natural resources. The human impact on the environment manifests itself at global to local scales. Population growth and legitimate attempts to improve standards of living are the major factors contributing to increased demands on the environment. Resultant environmental degradation can reduce the potential and real standards of living for all humankind. Short-term improvements in living standards, which can take place in years or decades, can exacerbate already existing problems, such as climate change, pollution, loss of soil fertility, and decreases in biodiversity.

Shortsightedness borrows resources from future generations to support current well-being. In many cases, there will be no way for current generations to repay future generations for using the resources. To understand the appropriate technological approaches and behavioral adaptations needed in our use of land resources, we must improve our knowledge of the resource systems. To do this, a basic set of data, analysis tools, and information must be available. The data are spatial and must represent physical, biological, and socioeconomic sectors of the environment. The tools, becoming increasingly sophisticated as computers become

faster and more powerful, include remote sensing, manned and unmanned field monitoring, geographic information systems, statistical analysis, and conceptual and numerical models. These are all components of modern decision support systems for natural resources. The information, a result of careful analysis of the data, is continually being improved as the scientific approach of questioning and testing the results is implemented. Adaptive management, a key to sustainabilty and improving living standards, depends on such an approach. The use of geographic information science can help developing nations exercise their legitimate right to improve the standard of living for their people while helping preserve natural resources for future generations.

Introduction

Garrett Hardin (1968) discussed three main topics in his paper, *Tragedy of the Commons*: (1) two variables cannot be maximized at the same time, therefore "the maximum good for the maximum number" is a nonsense statement, (2) there are some problems for which technological solutions are not sufficient and behavioral changes are required, and (3) common resources, when their use is not appropriately controlled, can be exploited to the advantage of individuals until they are overexploited and can no longer support the community or even those individuals.

An example of our inability to maximize two variables simultaneously is attempting to both increase population and increase standard of living in the same resource, technology, and behavior regime. If the population is held constant, the standard of living is increased until the capabilities and capacity of the regime are met. If the population increases, the demands on the regime may be such that the standard of living actually decreases.

Hardin's points are well illustrated by a community that holds land in common and allows grazing without restriction. Each member of the community attempts to increase his herd and so increase his wealth. This works well to a point, with the individuals and the community increasing in prosperity. Once the threshold is met, in this case the carrying capacity of the land, additional grazing animals diminish the resource until the carrying capacity of the land is decreased. At that point, the standard of living of the community and most, if not all, individuals in it begins to drop. That is the tragedy of the commons that Hardin discussed. The tragedy can be

forestalled by technological means, such as changing the feed grown on the land. However, that is only temporary. For a permanent solution, a behavioral change is necessary; that is, to recognize the limits of the resource and manage its use.

In situations where natural resources are being used, a sound information base is necessary to insure that human impacts are minimized or that the benefits are maximized. Although the information is necessary, it is not sufficient. A system approach has proven to be critical to determine what information is necessary for decision making (Scientific Assessment and Strategy Team (SAST), 1994; Kelmelis, 1995). For example, in response to the floods of 1993 in the Upper Mississippi River Basin of the United States, a simple input-output model was used to describe the system (see fig. 1). It addressed natural and human inputs to the river basin, how those inputs affected both the uplands and floodplains, how the uplands affected the floodplains, and how the changes to the uplands and floodplains affected the natural and cultural systems in which they reside. This conceptual model allowed for external inputs (the weather, grain prices, and national flood and crop insurance policies, for example), internal events (upland and floodplain floods, for example), systemic conditions and changes (river channelization, addition and removal of levees, land cover change, for example) and feedbacks (changes in demographics, land use patterns, and habitat variability, for example). Taking this system approach ensured that the data were gathered and analyses were conducted in such a way that the major policy and management issues were addressed (SAST, 1994; Interagency Floodplain Management Review Committee (IFMRC), 1994; Kelmelis, 1995).

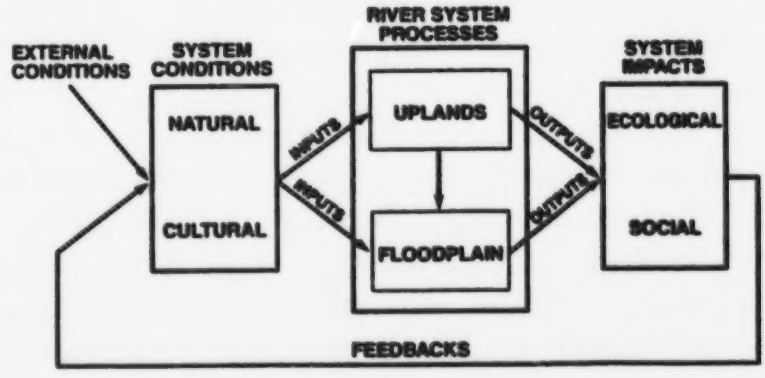

Figure 1. A simple system diagram showing the relationship of river basin system components when considering flood dynamics (from SAST, 1994).

This paper identifies (1) major issues in development, (2) major natural systems about which development decisions must be made, and (3) the basic spatial data needs and potential sources. Three examples of analyses and the data that were used for decision making are discussed; they are water retention practices in upland areas, natural habitat conservation in floodplain areas, and the impact and location of river training structures on a floodplain.

Major Development Issues

In both developed and developing countries, the principal development concern is to improve the health and well-being of the population; that is, raise its standard of living. Each nation uses a different strategy based on many factors to achieve this goal: its physical, biologic, economic, and human resources, its cultural biases, its state of development, its institutional and political framework, and its relationships with other nations. As a general rule, using basic economic sectors helps define the issues of concern. These sectors include agriculture, forestry, mineral resources, transportation, industry, commerce, tourism, communications, and information.

Examples of the physical resources include minerals, water, soils, climate, terrain, hydraulic potential, navigability, and geographic location and proximity. Examples of biologic resources include fish, animal, and bird stocks, timber stands, grazing lands, biodiversity, and so on. Human resources include the number, distribution, age profile, education, and physical condition of the population.

Development requires tradeoffs. They can include exchanging current resources and productivity for current benefits. If a long-term view is taken, development can also include the exchange of future resources and productivity for current or future benefits. Thus, any development that is undertaken has opportunity costs. An important issue of concern is that the current benefits may exhaust future opportunities; that is, current generations develop at the expense of future generations. In addition, there are spatial and socioeconomic tradeoffs. One region can develop to the detriment of others, and one segment of the population can develop at the expense of others.

Incorporating spatial scientific and socioeconomic data into the decision making process does not address all the issues, but it is relevant to most of the decisions on industry and natural resources. Although there are obvious economic benefits to

industrial and natural resource development, there can be long- and short-term economic and environmental costs as well. Some examples of these are described below:

- o Expansion of agricultural lands. Intrusion of agricultural lands into forested areas raises concerns of soil erosion, loss of carbon dioxide sequestration potential, fragmentation of ecosystems, loss of biodiversity, and loss of future timber harvests. Establishing agricultural activities in wetlands and on floodplains can eliminate the natural function of the wetlands to (1) store water and reduce peaks of floods, (2) provide natural filters that clean water, and (3) provide habitat for wild species that may be critical components of the environmental web.

- o Extraction of minerals. Mineral extraction can cause erosion, affect surface and ground water quality, mobilize toxic minerals, and alter land surface characteristics. As a result, resources must be expended in the future to stabilize the land surface disturbed by mining, to improve the quality of the water that may be affected by disruption of ground and surface water sources, and to establish more intensive medical treatment for people with illnesses related to toxic substances that may have been mobilized during mining.

- o Development of hydroelectric power. Hydroelectric dams alter flood regimes resulting in loss of habitat for aquatic species, and they alter sediment flow patterns, resulting both in loss of habitat and reduction in sediment available to maintain deltas and also in obstruction of pathways for migration of fish upriver and downriver and the flow of debris downriver.

- o Establishment of controlled river transportation routes. This includes the channelization of rivers, establishment of extensive floodplains, and incorporation of river training structures, such as wing dikes, levees, locks, and dams. These controlled routes alter the flow characteristics of the river, which in turn can reduce or increase available habitat, depending on the particular implementation, and can encourage human occupancy and development in the path of floods.

Although this list of development activities is far from exhaustive, it illustrates the potential impacts of development activities if they do not incorporate a long-term spatial view in their planning. To support planning and design of development projects that meet current needs while maintaining adequate resources to meet future needs, decision makers must understand the natural and socioeconomic systems involved. They must also have access to data with which to conduct analyses of potential alternatives and their likely impacts.

Major Natural Systems

Natural systems can be defined physically or biologically. The method of definition is principally a function of the variable of interest and spatial distribution. For instance, a river basin system is defined by the river and the area that contributes water to its flow, the drainage area; a boreal forest system is defined by the aerial extent of specific species of trees. In reality, however, both physically and biologically defined systems are physically driven. The river basin's spatial extent is defined by topography and the extent of the rivers within the system. The boreal forest exists in a particular place with its particular boundaries created by climatic factors, soils, cultural history, and so on, which, if changed sufficiently, would cause the demise of the species that compose a boreal forest. The place would then support another type of ecosystem, more or less desirable than the previous one (Kelmelis, 1996).

Systems vary in size and scale, can overlap, intersect, or abut, and can influence or be influenced by processes that operate at different spatial and temporal scales. A geographically based strategy for Earth system analysis is effective for resource planning in a global change environment. The global strategy described in Kelmelis and Ragone (1992) is modified here to address development issues from regional to local scales: (1) identifying management, policy, and stewardship concerns relevant to environmental change and the information needed to intelligently analyze them, (2) identifying regions on the basis of aggregates of topically relevant variables, (3) identifying the scientific research that must be conducted to understand how the system is affected by internal and external changes, (4) identifying the feedbacks and forcing functions from the system to the external system, (5) developing a management strategy to ensure that the research is effectively coordinated to gain the

maximum result for the least cost, and (6) managing the data and information so that they reach management and policy decision makers in a timely manner and a usable form.

A geographic focus is used to implement a strategy to consider the high variability of the terrestrial environment over different spatial and temporal scales. The variability is due to quantitative and qualitative differences of such factors as climate, terrain, land use and cover, cultural attitudes, political boundaries, and others, at specific geographic locations. Each set of variables can be aggregated to define regions. For instance, topographic features define physiographic regions (Fenneman, 1946). Aggregates of ecosystems define ecoregions (Baily, 1983, 1995; Omernik, 1987), and aggregates of vegetal types identify biomes (Udvardy, 1982). Climates can be defined regionally (Thornthwaithe, 1933; Trewartha, et al., 1967). Hydrologic units are catchments of various sizes where it is relatively easy, for the most part, to account for the mass and energy balance (Seaber and others, 1987). Human communities define political, economic, and land use regions. All of these regions operate as systems at some scale and contain subsystems that are significant at other scales. Development planning must consider the relevant systems to reduce the likelihood of unhappy surprises at some future time.

Not surprisingly, when analyzing Earth systems, basic sets of data are important regardless of the system and other sets of data are critical to analyzing specific issues within the system.

Spatial Data Needs

Although modeling the Earth system to address particular issues could require enormous amounts of data, there are a several initial core data sets that should be acquired because they are useful in many types of analyses. These may be augmented by improved and special data sets as time and resources allow or as required to answer specific research and policy questions. The International Symposium on Core Data Needs (ISCDN) for Environmental Assessment and Sustainable Development Strategies (Estes, Lawless, and Mooneyhan, 1994) identified 10 high-priority data sets that are central to many types of analyses necessary to produce sound development strategies. They are climatology, topography, soils, hydrology, land use and land cover, demographics, economy, infrastructure, air quality, and water quality. In

addition, data sets for specific resources and conditions are important. For instance, geologic information, such as mineral resources and surficial geology, and spatially referenced biological data are critical for many decisions. In many places these data do not exist or are not adequate. Although acquiring some of these data sets is becoming easier by remote sensing or remote monitoring networks as technological capabilities advance, direct field observations are necessary to (1) validate the interpretations of the remotely sensed data, (2) acquire data that cannot be sensed remotely, and (3) improve the quality of many data sets. Establishing acceptable standards and specifications is also necessary to ensure that any data acquired are suitable for the intended application. Data standards should be designed to ensure compatibility among the data categories. Consideration should also be given to ensure that the data have other broad applications as well, thus decreasing the long-term data costs.

Case Studies

During the late spring, summer, and early fall of 1993, devastating floods occurred in a large part of the Upper Mississippi River Basin (UMRB) in the United States. This flooding was the result of a persistent atmospheric pattern of excessive rainfall that occurred over much of the UMRB, which was already saturated from precipitation that began in mid-1992 after years of drought. A stable upper-level atmospheric pattern with a deep trough to the west of the upper Mississippi River valley and a strong ridge along the East coast of the United States sustained the excessive rainfall events through July. Then the trough shifted eastward, bringing drier conditions to the UMRB; however, localized flooding continued through October (IFMRC, 1994). The 1993 flooding in the UMRB was a devastating event resulting in the loss of 38 lives and between 10 and 18 billion dollars in damages.

The flood raised many questions, including these: How could a flood of this magnitude have happened? Did our policies contribute to the devastation? Will such an event recur? How can we reduce the risk to society in the future? If this is a natural event, are the natural parts of the system that are being hindered by our attempts to control it?

The Federal Government, recognizing the high cost of this flood and of possible subsequent floods, established the interdisciplinary, interagency Scientific Assessment

and Strategy Team (SAST) to help answer the above questions, to provide scientific advice and assistance to Federal officials responsible for making decisions about flood recovery in the UMRB, and to support the decision making process with information regarding both nonstructural and structural approaches to river basin management. The SAST was made up of senior scientists and engineers from throughout government and represented disciplines such as hydrology, hydraulic engineering, civil engineering, geology, geomorphology, geography, cartography, biology, ecology, economics, disaster management, soil science, and agricultural engineering. The team was assisted by other scientists throughout Federal, State, and local governments, private industry, not-for-profit organizations, and universities. It may be necessary to obtain support for this type of activity from donor nations or organizations.

Taking an interdisciplinary approach, the SAST evaluated the river basin system and its components. Using a geographic information system (GIS), the SAST built a 240-gigabyte digital data base. Using GIS, computerized mathematical models, and in-depth environmental system evaluation, the team conducted preliminary analysis and provided information and recommendations to policy makers and program managers. Data and information were gathered from numerous sources, including existing digital data, digitized maps, statistical tables, textual information, remote sensing analysis, interpretation of aerial photography, field observation and analysis, numerical modeling results, time series analysis, global positioning system, meteorological and stream gage networks, and others. The result is not only a data base useful for river basin management but also the beginnings of an integrated river basin management system that incorporates the needs of society and the natural environment.

A few of the studies are described here to indicate the types of analyses that can be conducted using spatial data for restoration and river basin management purposes.

Upland Land Treatment Flooding and erosion are problems that originate in the uplands before being concentrated in floodplains. Analysis of structural and nonstructural techniques to control them throughout the river basin is important. Studies conducted in sample watersheds in the UMRB have shown that the effectiveness of different land treatments varies depending on physiography (SAST 1994; Nicolini et al., 1997; Jorgeson and Johnson, 1997; Miller et al., 1997; Cooper, 1997). The watersheds used for land practice and land use studies were

selected to represent three distinct areas of the UMRB on the basis of the U.S. Department of Agriculture Major Land Resource Areas (MLRA). These were Boone River, West Fork Cedar River, and Whitebreast Creek. A fourth watershed, Redwood River, was used for a more detailed evaluation of the effect of wetlands on flooding. All watersheds were selected, in part, because of available data. The following alternatives were analyzed for the first three watersheds were:

1. maximizing wetland storage in upland and (or) floodplain areas as applicable,
2. converting cropland to Conservation Reserve Program[1] (CRP) as available,
3. maximizing infiltration by using all applicable land treatments, such as conservation tillage, terraces, and permanent cover,
4. installing flood prevention structures as applicable, such as small water detention structures designed to temporarily store water and release it slowly,
5. combining all nonstructural practices (a combination of 1, 2, and 3), and
6. combining all possible alternatives (a combination of 1, 2, 3, and 4).

The fourth watershed was specifically selected to determine the effect of wetlands; therefore, no CRP or maximum infiltration methods were analyzed.

The analysis proved that physiography is important in determining the effectiveness of various land management practices. No one technique was uniformly effective among the different physiographic regions. Applying different land management techniques in different geographic locations could improve water retention and infiltration, alter flood stage and flow, and, as a result, control erosion and deposition of topsoil. This is important to the long-term productivity of agricultural lands, maintaining the appropriate flood flow regime, managing the risk of flooding, and managing the erosion and sediment regime to maintain a dynamic geomorphology on floodplains and ensure the viability of delta regions.

Although several hydrologic and hydraulic models can be used to conduct this type of analysis, they depend on a standard set of information that is contained in

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[1] The Conservation Reserve Program (CRP) was introduced in 1985 to provide payments to farm operators who agreed to temporarily protect highly erodible lands. As of 1995, 36.4 million acres enrolled in the CRP were scheduled to begin coming out of the program (IFMRC, 1994).

selected cartographic data sets described above. The data sets are climatology and meteorology, topography, soils, hydrology, land use and land cover, and infrastructure. Pseudo data (hypothetical data that are developed for and by models to test various scenarios) are also used to test potential changes to the real world conditions described in the cartographic data sets.

Floodplain Levee Placement Levees, dikes, wing dikes, maintained channels, dams, and locks are river structures that alter the flow characteristics of a river. As a class, they are designed to allow specific activities to take place in an area that is not capable of sustaining them in the natural state. For instance, maintained channels are designed to allow navigation of a river by vessels of a larger size than would be possible under natural conditions, dams can be used to control flow on a river by attenuating peak and low flows, locks allow navigation up a river whose gradient is too steep for navigation in its natural state, and levees allow use of floodplain lands for dry land activities even when the river is at a certain flood stage. All of these structures can be effective within design limits and can provide significant economic benefits if planned, designed, and used wisely. However, if the population using the resource does not understand the limits, catastrophic results can ensue. Long-term maintenance costs can also be significant and can exceed benefits.

Analysis of levee breaches along the lower Missouri River indicates clearly that the physical environment plays an important role in the location of breaches. Examining the history of levee damage for the levee districts revealed many repeat breaches. One levee district, Lisbon Bottoms, has been breached or overtopped on the average of once every 3.9 years since 1943. Thus, approximately every four years the people and property protected by that levee were adversely affected by flooding. Further analysis of levee breaches showed that most occurred where the current channel crossed historic river channels, in high-energy reaches, and near tributaries and chutes. The following factors contributed to the levee breaks:

1. highly permeable substrata composed of channel sand, with or without a thin silt-clay cap;
2. channel banks subject to high-energy flow conditions at
   a. downstream banks of meanders between points of initiation and inflection and

b. channel banks opposite deflecting cross flows on a tributary, chute, or flood channel;

3. levee irregularities and (or) discontinuities at
   a. high-angle junctions between levee segments and
   b. repaired levees that ring old levee scour holes;
4. inadequate levee design, construction, and repair; and
5. inadequate levee maintenance.

Geomorphic mapping showed that catastrophic levee failure most frequently occurred at the following places:

1. areas of high-amplitude and short-wavelength meanders (loop bottoms),
2. long-bottom areas where remnants of historic channels intersect the upstream end and extend along much of the length of the long bottom, and
3. areas with significant floodplain constrictions (artificial structures, such as bridges, powerplants, and so on).

This analysis indicated that a decision model for rational placement of levees could be designed to minimize risk of (1) people and property being placed in harm's way, (2) frequent levee breaches and costly levee repairs, (3) catastrophic failure causing destruction of critical infrastructure, and (4) a downstream hazard caused by mobilization of hazardous material stored behind levees.

Although historic data are not available for all places, much information for making decisions can be gained from recent data, including topography (to support hydraulic models and geomorphic analysis, and identify current high energy zones); surficial geology (to identify soil and surficial material types that indicate the location of historic channels, engineering properties of surface materials and their suitability for use as levees or the area on which to construct levees, and identification of previous high-energy zones); land use and land cover (to identify the types of biological and infrastructure resources that are at risk and may need special protection); infrastructure (to identify constrictions on the floodplain and critical cultural resources that may be at risk); hydrology (to provide an understanding of potential flood flow characteristics); climatology and meteorology (to provide an understanding of the potential frequency of extreme events that may cause flooding); and economics (to evaluate the existing and potential value of the lands being placed under protection, as well as the opportunity costs of altering the flood flow

characteristics). Combining the appropriate data from these data sets will identify the active floodway; that is, the area of highest risk on the floodplain. Avoiding that area can help reduce risk to people and property and help prevent frequent costly repairs. The active floodplain is critical to ensuring the existence of viable aquatic habitat.

Aquatic Habitat Maintenance Many benefits accrue to societies that maintain viable aquatic habitats on their rivers and streams. These include subsistence and commercial fishing industries, higher quality water, improved aquaculture, aquatic ecosystems as a support for other wildlife groups, and attractive resources for tourism.

Important aquatic habitat restoration objectives were outlined by the National Research Council (1992). Briefly, they consist of (1) restoring the natural sediment and water regime, (2) ensuring that the natural channel geometry is maintained, (3) ensuring that the natural riparian plant community is a functioning part of the channel geometry and floodplain/riparian hydrology, and (4) restoring the native plant and animal community if it does not restore itself. Those objectives are also guidelines for ecosystem maintenance because they represent a dynamic equilibrium of the floodplain ecosystem and the geomorphology on which it is based.

Protecting the active floodway from manmade obstructions is an excellent way to ensure the dynamic equilibrium; however, at times such obstructions are necessary for economic development, Also, there may be river reaches whose floodplain cannot be fully maintained. In those instances, selecting high-priority sites for restoration or maintenance may be an acceptable approach to ensuring a sustainable level of aquatic habitat. The SAST members and scientists who worked with them prepared a data base of high-priority aquatic restoration sites on the middle and lower Missouri River. SAIC (1994) reported the criteria used by SAST to develop that data base. Further examination of those criteria indicate that they fell into four categories: physical, biologic, biophysical, and economic.

Physical criteria

1. Proximity to river. This is determined by topographic and hydrologic information. Is the parcel of land located sufficiently near the river to provide accessible and protected habitat and spawning areas during critical times in the life cycle of target

species, yet sufficiently close to other critical parts of the ecosystem?

2. Structural diversity (for example, sand bars, islands, and cliff faces). This information is found by analyzing the topographic, geologic, and hydrologic data bases.
3. Structural uniqueness (for example, oxbows, sloughs, and side channels). This information is determined by analyzing topographic, geologic, and hydrologic data bases.
4. Connectivity or "linkability" (that is, can the parcel be linked with others to form a more ecologically functional pattern?). This information is obtained by evaluating the map of the parcel of interest in conjunction with other parcels of interest or others that have already been acquired. This is derivative information from other data bases and the current analysis.

Biological criteria

5. Number of species present. The biologic data bases provide this information. Spatial and temporal characteristics of the life cycle, species and community productivity, and vulnerability of the population, are important as well as species type and counts.

Biophysical criteria

6. Parcel size. The parcel should be large enough to meet the habitat maintenance or restoration criteria. The target parcel is identified and outlined on the basis of the other criteria. Ideally the parcel is owned by one individual or organization for ease of acquisition; however, more often several pieces of land owned by a number of individuals or groups must be acquired to make a parcel of sufficient size.
7. Rarity of habitat. This information can be derived from the biologic and land cover data bases.
8. Presence of critical habitat. The biologic, topographic, and land cover data bases provide this information. Evaluation of the relationship of species' life cycles with land characteristics and

available habitat types helps ecologists and biologists identify critical habitat locations.

Economic criteria

9. Willing sellers. The willing sellers are identified in the local economy through indirect or direct inquiry. This is a highly dynamic variable, both temporally and spatially, and must be assessed on a case-by-case basis.
10. Targeted area. (That is, is this parcel already in a plan for acquisition for another reason, and can it be used simultaneously for the habitat maintenance or restoration purpose? Is there a possibility for multiple, nonconflicting land uses?)
11. Threat of development pressures. (That is, do plans for long-term management of the river identify this area for development? If so, the future land use should be adjudicated in advance to prevent conflicts and loss of critical habitat in the future.)

These criteria are based on an analysis of data bases, plans, local interests, and knowledge of the aquatic ecology. Proper decisions early in the planning and development process can ensure the maintenance of aquatic habitat and the attendant environmental and economic benefits it provides.

Information Availability

Providing the results of management and policy relevant research to the decision makers in a timely manner takes a concerted effort. It is important not only to provide the information, to make it available in a form that the decision maker can use. Although printed maps and reports have been the standard for many years, the digital information age has provided opportunities to supply information to managers faster than ever before. These opportunities are greatest in the developed countries where the information infrastructure is more mature. However, developing countries will obtain significant benefits as they acquire greater access to stable power sources, adequate telecommunications capabilities, and more sophisticated hardware and software. Dropping prices for these items combined with an obvious need for

international interdependence in development can accelerate an improving intrantional and international information infrastructure.

Already there are a number of data bases and clearinghouses serving available data and technology on the Internet through the World Wide Web (WWW) including the following:

- Environmental Information System for the Upper Mississippi and Lower Missouri River Basins (often called the SAST data base) was established by the SAST in response to the floods of 1993 in the UMRB to provide data and information to managers, policy makers, researchers, and others for flood recovery and river basin management. It contains more than 240 gigabytes of data; some can be served online and some must be served offline because of size. The clearinghouse links Federal agencies, States, nongovernment organizations (NGO's), and similar clearinghouses in the international community. The WWW address is <http://edcwww2.cr.usgs.gov/sast-home.html>.
- Mojave Desert server is a point of distribution for data that have been assembled to help managers and policy makers make decisions with respect to ecologic recovery and sound environmental management of current and future projects in the Mojave Desert. Its WWW address is <http://mojave.army.mil/>.
- The United Nations Environment Programme (UNEP) maintains a series of nodes throughout the world to improve access to data that nations can use for environmental analysis. The Global Resource Information Data Base (GRID) for North America is maintained by the U. S. Geological Survey at the Earth Resources Observation System (EROS) Data Center (EDC) and can be accessed on the WWW at <http://grid2.cr.usgs.gov/>.
- The Inter-American Geospatial Data Network (IGDN) is supported by the U.S. Agency for International Development to encourage environmentally sound, broad-based economic growth and free trade in the Western Hemisphere through improved access to geospatial data for business, NGO's, and governments in the region. The project promotes implementing Internet capabilities internationally and has international cooperators in both the public and private sectors. Its WWW address is <http://edcintl.cr.usgs.gov/igdn/igdn.html>.

- The Africa Data Dissemination Service (ADDS) has been established to improve access to and use of geographic data and data communication on the African continent by linking continental, regional, and national data sets served by various organizations through a distributed clearinghouse. The home page and links to participating file servers can be accessed at <http://edcintl.cr.usgs.gov/adds/>.
- The Famine Early Warning System (FEWS) is a multi disciplinary project that provides subnational information to decision makers about potential famine situations in Africa. It can be reached at WWW address: <http://edcintl.cr.usgs.gov/adds/general/project.html>.
- The National Biological Information Infrastructure (NBII) is designed to increase access to and application of biological data and information from a distributed network of numerous domestic and international sources. It can be reached on the WWW at <http://www.nbs.gov/nbii/>.

Examples of how available data have been used to make management decisions include following: data from the SAST data base have been used for many purposes, including locating habitat restoration sites that have been purchased as part of the Big Muddy Wildlife Refuge and identifying sites containing toxic materials that were inundated by the flood of 1993, thus identifying which toxic substances might have been mobilized by the flood waters.

Making the data and information available is not sufficient. A practical approach to facilitating data use by decision makers includes providing data and analysis results in various formats so they can be understood and used by many clients. Some formats are fact sheets (one- or two-page documents that describe a technical analysis and results in non-technical terms), management reports, scientific reports, maps, data bases, demonstrations, and presentations. Some of these may be provided in hard copy or on a digital information network like the Internet. These products must be presented in such a way that decision makers can understand them. Timing is also important. For instance, there is heightened awareness of the natural hazard for a short time after a natural disaster. Usually decision makers and the general public are more receptive to using scientific information to help reduce current and future losses at that time.

Conclusion

Managing the environment as a system rather than as a series of independent projects is more effective in the long run. Experience has shown that the long-term maintenance of ecosystems provides important economic benefits and that the degradation of ecosystems has ongoing costs. Developing multi scale, spatially referenced data bases of critical variables that can be used to help make resource management and development decisions is a wise investment in the future. Certain identifiable variables should be part of the base data available to researchers, planners, policy makers, and managers. If those data are readily available to a wide segment of the population, it is likely that more in-depth and creative analysis will take place.

Data from the data bases are being used by decision makers within the United States for land use and resource planning, recovering from disasters, and biophysical analysis. For example, more than 750,000 digital data files were transferred from the Environmental Information System for the Upper Mississippi and Lower Missouri River Basins between June 1995 and January 1997. During that 18-month period, many of the data were used for research but many were also used to make decisions on the management of the river basin.

There are several things that can be done to make the data and information more valuable:

(1) Improve the data and information infrastructure and make it more accessible to the general population, as well as to the managers and policy makers. This is particularly important in the developing nations, where sound decisions in the early stages of development can prevent costly corrective actions in the future.

(2) Make the infrastructure compatible with inexpensive, readily available equipment.

(3) Improve the availability, ease of use, and understandability of the tools used to apply the data.

(4) Present the analytical results in such a way that they are easy to understand and apply.

(5) Ensure the data and information upon which the analysis must be based exist and are readily accessible.

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COUNTRY REPORTS

Cooperation between official mapping agencies in Europe

Paper submitted by the Comité Européen des Responsables de la Cartographie Officielle (CERCO)**

* E/CONF.90/1.

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CERCO was founded in 1980 by five governmental mapping agencies in Europe. Currently, it has 34 members, either full-members or observers. CERCO has normally one General Assembly in a year organised by a member agency. Besides the General Assemblies, the work of CERCO will be carried out through a Management Board, Working Groups and by correspondence. CERCO has a part-time secretary.

The Management Board is composed of the President and ex-president or incoming president and three elected members.

The principal purpose of CERCO is to encourage the exchange of information on matters of mutual concern between the national mapping agencies of Europe and, by so doing, to strengthen the co-operation between its members.

CERCO also wants to secure and reinforce the presence of itself and its members in all fields of the cartographic and geographic information community in Europe, taking into account the needs existing in the market.

Furthermore, CERCO tries to identify subjects for which common policies are appropriate, assist in their formulation, and encourage their acceptance by all those involved.

CERCO has currently four working groups, which are open for all members. One is dealing with copy-right and legal issues, one with geodesy, one with updating of databases and the newest one with the quality problems of digital databases. Working groups give their progress reports annually to the General Assembly of CERCO.

More information will be provided by the Secretary General of CERCO, Mr John Leonard, whose official address is:

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MEGRIN (Multipurpose European Ground Related Information Network)

An urgent need of pan-European digital geographic data sets was recognized by CERCO in the early 1990's. It started the process by the end of which the MEGRIN GIE was established in 1995 by 19 CERCO members under the French law in Paris. MEGRIN GIE has produced so far two products; GDDD and SABE.

GDDD - Geographic Data Description Directory, helps you to find European digital geographic information which you need. More than 36 National Mapping Agencies (NMA) have described their own datasets.

SABE - Seamless Administrative Boundaries of Europe, contains detailed administrative boundaries for 25 European countries.

MEGRIN GIE has also started *a PETIT - project, Study of European Topographic Data.* As Europe becomes more closely linked, pan-European topographic data will become increasingly important. Organisations need to be able to monitor their activities using reliable and comparable data. Digital maps at the scale of 1 : 250 000 may well be appropriate for applications at European level. PETIT is a study to investigate the feasibility of using the Vmap level 1 specifications created by the National Imagery and Mapping Agency as the first step in creation of data meeting a common specification.

More information is available from the MEGRIN secretariat:

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CERCO *and the pan-European geographic information policy*

There is an urgent need of pan-European harmonious, homogenious digital geographic datasets. The problem is that mapping and geographic datasets in general are very national by nature.

The Commission of the European Union has therefore started to prepare a document (Towards a European Policy Framework for Geographic Information, November 1996, GI 2000 Initiative), which describes the principles, procedures, practices and issues in general, which are necessary in creation of European geographic information policy. It is intended to give this document in the form of the Communication to the Parliament of the European Union and to the Council of Ministers of the European Union. This is expected to happen in the very near future.

This activity pursues the same objectives, which in the United States were launched by President Clinton in his Executive Order on 11 April 1994 to set up the National Spatial Data Infrastructure.

CERCO and its members have been working in close co-operation with the Commission in drafting the document.

CERCO has stressed especially the following points:

- There is an urgent need for geographic base data as a part of an information infrastructure for the whole of Europe. Its creation and subsequent maintenance need to be ensured.

- Despite the essential and long-term benefits to be enjoyed from having an effective pan-European information infrastructure, there are significant start-up costs and managerial and technical challenges to be met. Expecting market forces to care for these is unrealistic.

- National Mapping Agencies already hold large volumes of geographic data. The huge investments made in national digital data makes a failure if exploited in an unthinkable way. CERCO believes that the creation of pan-European geographic base data will be cheaper if existing national data forms the basis of the process, even if there will be additional costs in converting national data to European data.

- The resources of NMAs are appropriate to finance only national responsibilities. Thus it falls to CEC to find funding for the additional effort. CEC will have to continue to take the lead by creating the appropriate financial and political climate and by co-ordinating the various interests if the initiative is to progress.

- If a Task Force is set up for carrying on the GI2000 initiative, CERCO would want to be involved.